

# Direct Detection of Dark Matter and Underground Facilities:

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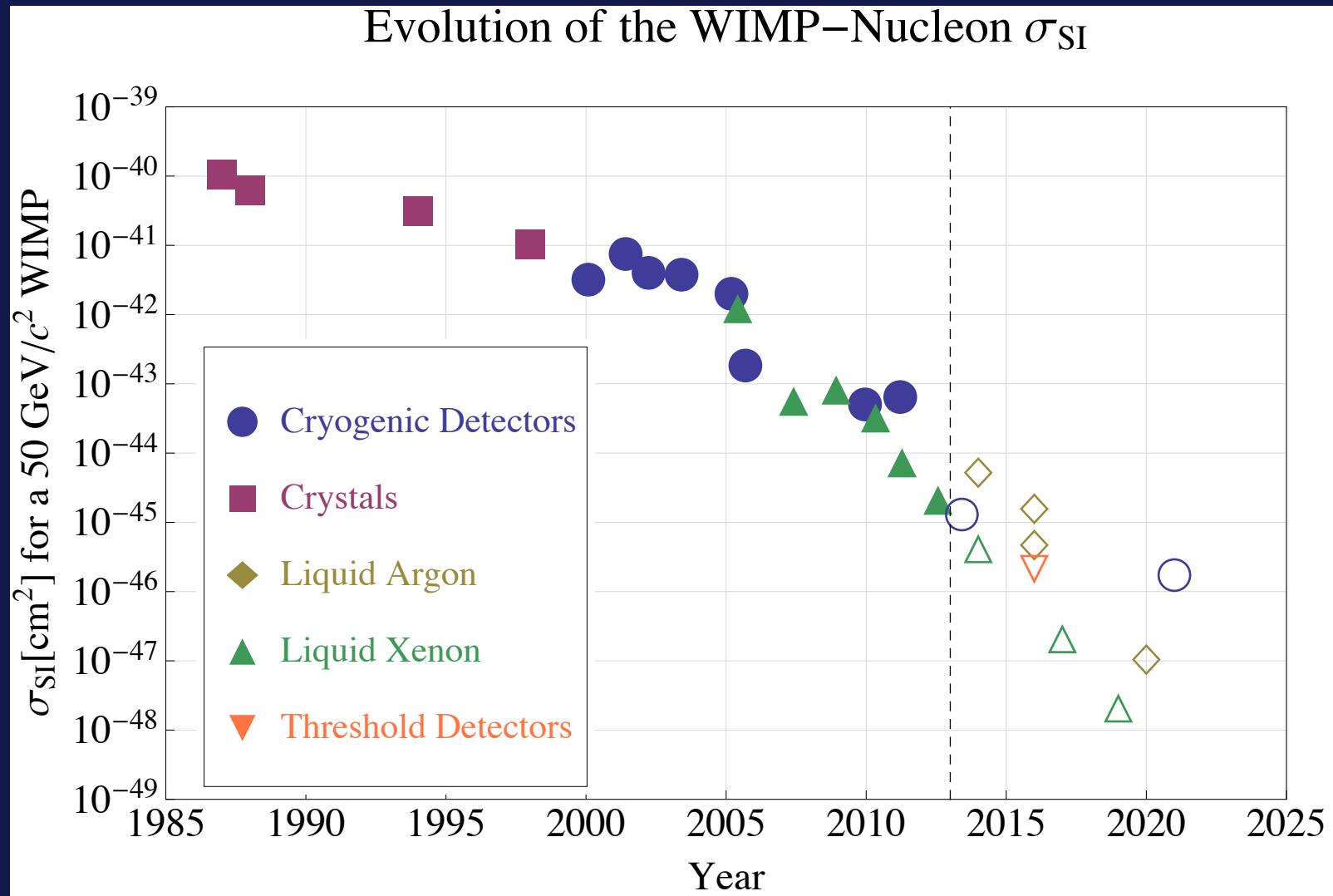
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# The Dark Matter Campaign

- An Assessment of the Science Proposed for the Deep Underground Science and Engineering Laboratory (Lankford Report, National Research Council, 2011)
  - "The direct detection of dark matter would provide a crucial experimental connection between particle physics and cosmology.
  - To be definitive, their signature signals would need to be significantly above the background and would need to come from different experiments....
  - The program in dark matter detection will by necessity involve a number of G2 experiments that will coalesce into a smaller number of highly sophisticated and massive G3 detectors."

The campaign is advancing  
to the G2 experiments.



There could be a discovery at any time.  
(Future dates are subject to change.)

# G2 experiments

- G1 experiments are those operating now.
- The DOE will select 1 or more G2 experiments in late 2013 for construction start in late 2014.
  - NSF will have a parallel process.
  - Other experiments around the world are also under construction or will be by 2014. We will consider these experiments as G2 also, although their timing is not determined by the U.S. process.
- It is important that the G2 experiments be given a fast funding start.

# Facilities for the G2 experiments

- The current underground facilities can meet the needs of the proposed G2 experiments.
  - Sanford Laboratory (SURF) – LZ
  - SNOLAB – SuperCDMS, COUPP, DEAP
  - Gran Sasso Laboratory (LNGS) – XENON1T, DarkSide-G2
  - China Jin-Ping Underground Laboratory – PandaX II
- The experiments will make excellent use of the facilities through about 2019.
- It is critical that these facilities continue to operate throughout the operating period for the experiments.

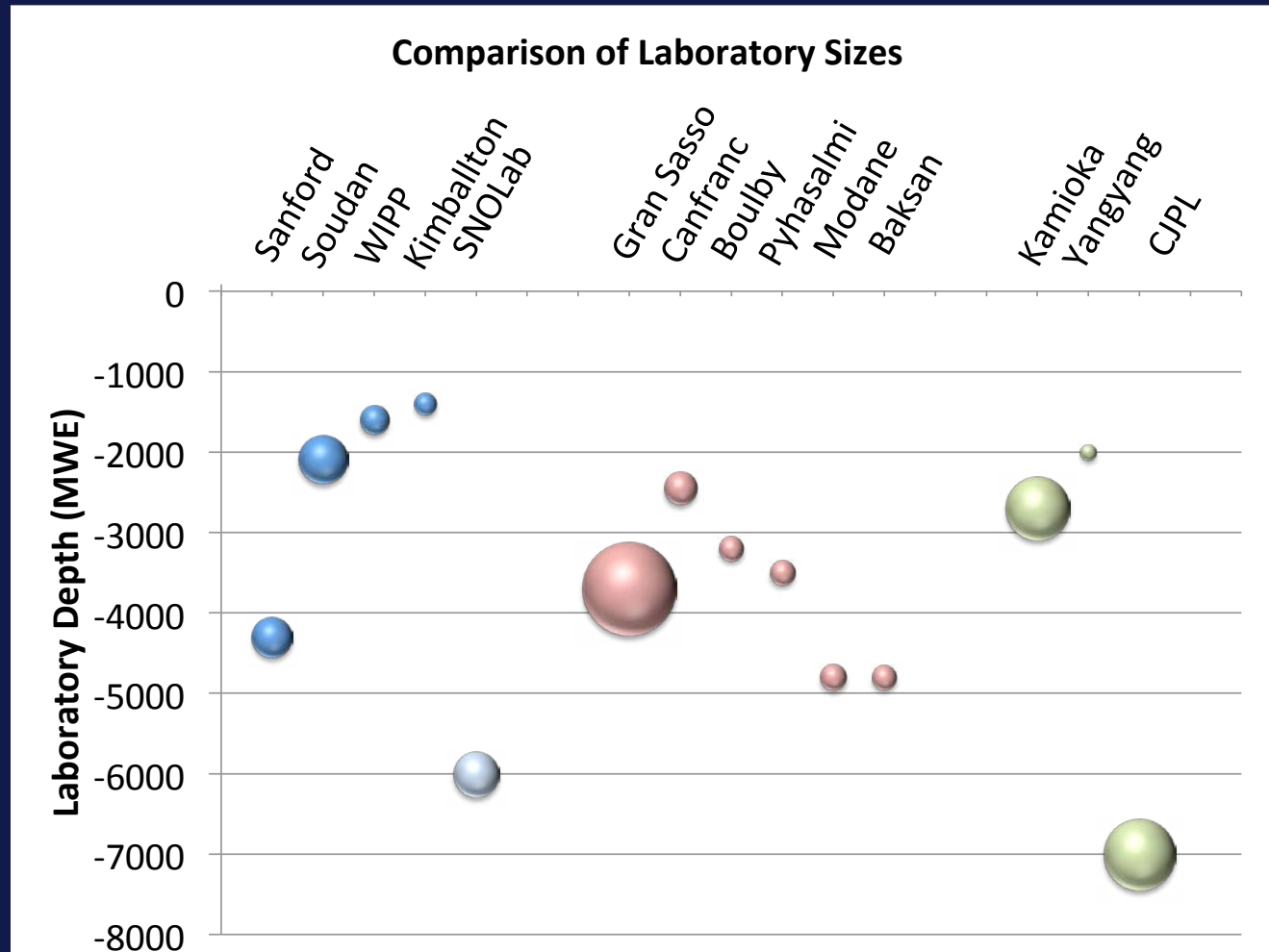
# G3 experiments

- Experiments beyond the G2 round are considered to be G3.
  - Fiducial mass is likely to be 5-10x greater than the corresponding G2 experiment.
  - A G3 experiment is likely to cost of order \$100 M.
  - The number of G3 experiments will be smaller than of G2 experiments: 2-5 worldwide.
  - US scientists will participate in most G3 experiments and will take a leading role in some.

# Facilities for G3 experiments

- The G3 DM experiments will require large, deep underground halls with excellent services.
  - How deep?
  - How large?

# Depth



- The G2 sites range in depth from 3600-7000 m.w.e.

# How deep must the G3 experiments be located?

- All of the G2 sites may well be deep enough to host a G3 experiment ( $>3400$  mwe)
  - Cosmogenic neutrons do not dominate the present experiments.
  - Advanced veto/shield systems reduce backgrounds.
  - Solar neutrinos are likely to be the dominant source of backgrounds for G3 experiments.
- The experience of both solar neutrino detectors and G2 DM experiments with advanced veto/shield systems will be used to determine the extent of active background reduction needed by G3 experiments.

# Are present deep sites large enough for G3 experiments?

- The shield/veto systems needed to reduce backgrounds in a multi-ton G3 experiment determines the size of the hall needed.
- Only a few of the largest of the existing and planned underground halls can accommodate such an experiment.
- Currently no US sites are capable of hosting an experiment of the probable G3 scale.
  - For any G3-scale experiment at Sanford, a new hall would need to be excavated.

# Directional Detection

- If the current R&D on directional detection experiments is successful, large experiments will be proposed.
- The first round of such experiments will compete for space at existing underground facilities.
- It is too early to specify what space will be required for directional experiments that might be built in the G3 era.

# The International Program

- Experiments in the U.S. DM program are deployed in U.S., Asia, Canada, Europe, and Antarctica.
- This arrangement has arisen naturally from the international nature of particle physics collaborations.
- It is critical that an open access policy – like those now in place at major underground facilities – continue to be followed.

# The international network of underground facilities

- Each major country (or region) should support at least one major underground facility capable of hosting the forefront experiments.
  - Each of these facilities will support some of the leading underground experiments.
  - Scientists from many countries will work on the experiments at each facility.
- This is a sustainable model for the international support of underground physics.

# Underground Facilities in the U.S.

- The U.S. will continue to take a strong leadership role in the worldwide dark matter campaign through the G3 era.
  - Presently 40% of the international community
- The U.S. should maintain an underground facility capable of handling the largest DM experiments.
  - This would guarantee the ability of the US to continue its strong role in the worldwide program.
  - The existence of such a facility would make it possible to initiate new experiments with minimum delay and minimum possible cost.

# Conclusions I

- All the next generation (G2) dark matter experiments can be accommodated by existing and planned underground facilities, assuming no reduction in these facilities.
- U.S. physicists are participating in most G2 experiments around the world, representing 40% of the community, and they are leading many of them.
- A G3 experiment is likely to be 5-10x the volume of the G2 experiment of similar technology and mass reach.

# Conclusions II

- It seems likely that all the G2 facilities will have sufficient depth for a G3 experiment.
- The U.S. does not now have a deep underground hall large enough to house a large G3 experiment.
- The U.S. should maintain an underground facility capable of handling at least one of the largest G3 experiments.